

Production of $\pi/K/p$ from intermediate to high p_T in pp, p–Pb and Pb–Pb collisions measured by ALICE

Antonio Ortiz Velasquez (for the ALICE Collaboration)^a

Lund University, Department of Physics, Division of Particle Physics Box 118, SE-221 00, Lund, Sweden

^a*Now at: Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apartado Postal 70-543, México D. F. 04510, México.*

Abstract

In this work the results on the transverse momentum distributions ($\sim 0.3 < p_T < 15$ GeV/c) of charged pions, kaons and (anti)protons, measured in pp and Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, are presented. The evolution of the spectral shapes and particle ratios with multiplicity is shown and the similarities among the different systems are discussed.

Keywords: proton nucleus reaction, light hadrons, LHC, collectivity.

1. Introduction

In central heavy ion collisions at ultra relativistic energies it is well established that a strongly interacting medium of quarks and gluons is created. The transverse momentum, p_T , distributions of identified hadrons contain valuable information about the collective expansion of the system ($p_T \lesssim 2$ GeV/c), the presence of new hadronization mechanisms like quark recombination ($2 \lesssim p_T \lesssim 8$ GeV/c) [1] and, at larger transverse momenta, the possible modification of the fragmentation due to the medium [2, 3]. ALICE has reported the transverse momentum spectra, as a function of the collision centrality, of charged pions, kaons and (anti)protons from low (hundreds of MeV/c) [4] to high (20 GeV/c) [5] p_T . From the analysis of the low p_T results in the most central collisions, the radial flow, $\langle\beta_T\rangle$, is found to be $\approx 10\%$ higher than at RHIC, while the kinetic freeze-out temperature was found to be comparable to that extracted from data at RHIC, $T_{kin} = 95$ MeV [4]. The spectra are well described by hydrodynamic models, except the low p_T (< 1 GeV/c) proton yield [6–9]. Models which best describe the data include hadronic rescattering with non-negligible antibaryon annihilation [8, 9]. For intermediate to high p_T (> 3 GeV/c), the spectra develop the power law tail characteristic of hard partonic processes. The proton-to-pion ratio increases from ≈ 0.38 to ≈ 0.8 going from peripheral (60–80%) to central (0–5%) Pb–Pb collisions at $p_T \approx 3$ GeV/c, then decreases to the value measured for vacuum fragmentation (pp collisions) for $p_T > 10$ GeV/c. The result obtained for the most central collisions is similar to that measured at RHIC [10, 11]. The kaon-to-pion ratio also exhibits a small bump around $p_T = 3$ GeV/c. Quark recombination does not predict the latter effect and fails to describe the p/π ratio over the entire p_T range.

Surprisingly, early results from LHC showed that p–Pb collisions exhibit behaviours reminiscent to those due to final state effects, namely, hints of collective effects (radial and elliptic flow, ridge structure), but no sign of jet quenching [12, 13]. Hence, the main focus of this work is to present complementary measurements on identified particle production, $\pi/K/p$, from intermediate p_T , 2–3 GeV/c, to high p_T , < 15 GeV/c, in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.

Email address: aortizve@cern.ch (Antonio Ortiz Velasquez (for the ALICE Collaboration))

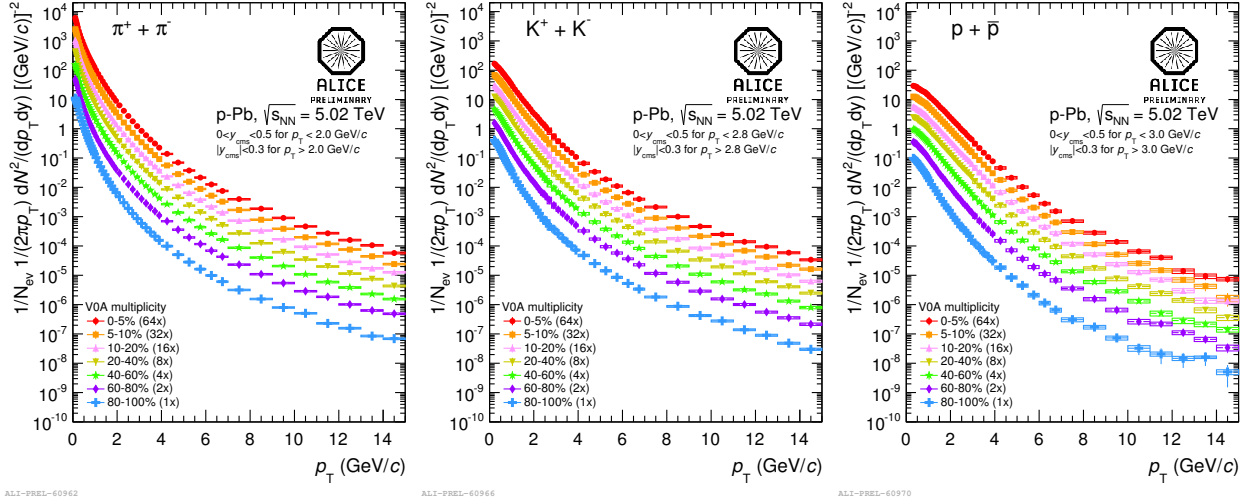


Figure 1. p_T spectra of charged pions (left), kaons (middle) and (anti)protons (right) measured in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV for different V0A multiplicity event classes. The systematic and statistical error are plotted as color boxes and vertical error bars, respectively.

2. Analysis method

Data from p–Pb collisions were obtained using the ALICE detector [14]. In the analysis presented here, we have used 82 millions minimum bias (MB) events. The MB trigger signal was provided by the VZERO counters, two arrays of 32 scintillator tiles each covering the full azimuth within $2.8 < \eta_{lab} < 5.1$ (V0A, Pb beam direction) and $-3.7 < \eta_{lab} < -1.7$ (V0C, p beam direction). The signal amplitude and arrival time collected in each tile were recorded. A coincidence of signals in both V0A and V0C detectors was required to remove contamination from single diffractive and electromagnetic events. For p–Pb collisions, the nucleon-nucleon center of mass system has a rapidity of $y_{NN} = -0.465$ in the direction of the proton beam. Due to the weak correlation between geometry and multiplicity, the particle production is studied in seven multiplicity event classes instead of centrality, this selection was based on cuts on the total charge deposited in the V0A detector [13]. Particle identification at high p_T is done using the specific energy loss, dE/dx , measured in the Time Projection Chamber (TPC) for tracks in $|y_{cms}| < 0.3$. The yields ($dN/dydp_T$), particle ratios as a function of p_T and their uncertainties are obtained using the method discussed in this reference [5]. The main quantities to determine the yields are the particle fractions as a function of p_T , *i.e.*, the contribution of a given particle species to the yield of inclusive charged particles in a given p_T interval. They are determined from a four-Gaussian (pions, kaons, protons and electrons) fits to the dE/dx spectrum where all the means and widths are constrained using enhanced pion, proton and electron samples.

3. Results

The transverse momentum spectra of charged pions, kaons and (anti)protons are shown in Fig. 1 for the seven V0A multiplicity event classes measured in p–Pb collisions. The low p_T results have been already published [13] and here the p_T reach is extended up to 15 GeV/c. For p_T below 2 GeV/c the spectra become harder as the multiplicity increases and the effect is stronger for heavier particles. This feature is well known from heavy nuclei collisions where it is attributed to the hydrodynamical evolution of the medium, and in fact the p_T spectra measured in high multiplicity p–Pb collisions are better described by models which incorporate hydro [13]. However, it has been shown that also in pp collisions simulated with Pythia 8 tune 4C [15] the p_T spectra of identified particles as a function of multiplicity exhibit a qualitatively similar behaviour to that seen here. This behaviour is a consequence of the interactions among final partons coming from independent semi-hard scatterings which increases with increasing number of multi-parton interactions (MPI) [16].

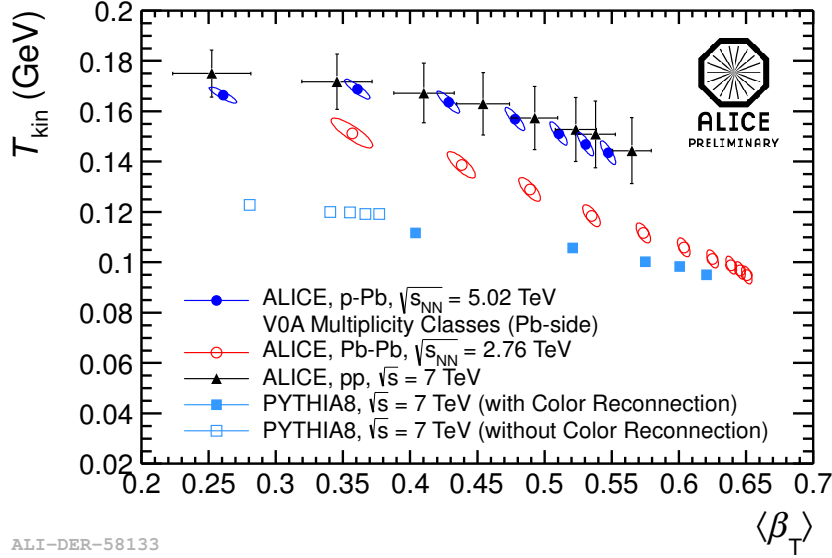


Figure 2. Comparison of the results from the blast-wave analysis applied to all available systems: pp, p–Pb and Pb–Pb collisions. The spectral shape analysis was also applied to Pythia 8 events. Charged-particle multiplicity increases from left to right

One therefore cannot rule out alternative explanations, but interestingly, it illustrates that likely there is a strong coupling of this phenomenon to the underlying event also in pp collisions. To study the evolution of the spectral shapes with multiplicity the blast-wave analysis has been performed and the results are shown in Fig. 2. This allows a comparison of the results from different colliding systems (pp, p–Pb and Pb–Pb) using a set of two parameters, which, in heavy ion collisions are typically connected with T_{kin} and $\langle\beta_T\rangle$. Figure 2 shows that a qualitatively similar behaviour is obtained for the three systems which were analysed, even in Pythia 8 events simulated with color reconnection. To study the effect on the p_T spectra directly, the proton-to-pion ratio was constructed, the results for p–Pb and Pb–Pb collisions are presented in Fig. 3 for two extreme multiplicity intervals. For p_T below (above) 2 GeV/c the ratios exhibit a depletion (enhancement) going from low to high multiplicity. The highest (lowest) multiplicity intervals give ratios which reach maxima at $p_T \approx 3$ GeV/c amounting to ≈ 0.4 and ≈ 0.8 (≈ 0.28 and ≈ 0.38) in p–Pb and Pb–Pb collisions, respectively. Above 3 GeV/c, the ratios start to decrease down to ≈ 0.1 at $p_T \approx 10$ GeV/c, which according to [5] corresponds to the value measured for vacuum fragmentation (pp collisions).

4. Conclusions

In this work the production of $\pi/K/p$ measured in p–Pb collisions have been presented up to $p_T = 15$ GeV/c. The baryon-to-meson ratios measured in p–Pb and Pb–Pb collisions show an enhancement with respect to pp collisions which reach their maxima at $p_T \approx 3$ GeV/c and for higher p_T (> 10 GeV/c) the ratios return to the value obtained for pp collisions. The evolution of the spectral shapes with the event multiplicity has a similar mass dependent systematics as observed in heavy nuclei collisions where it is associated to flow. Hydrodynamical calculations give the best description of the high multiplicity p_T spectra in p–Pb and Pb–Pb collisions, but other mechanisms like MPI plus color reconnection also can produce flow-like patterns without the presence of any medium.

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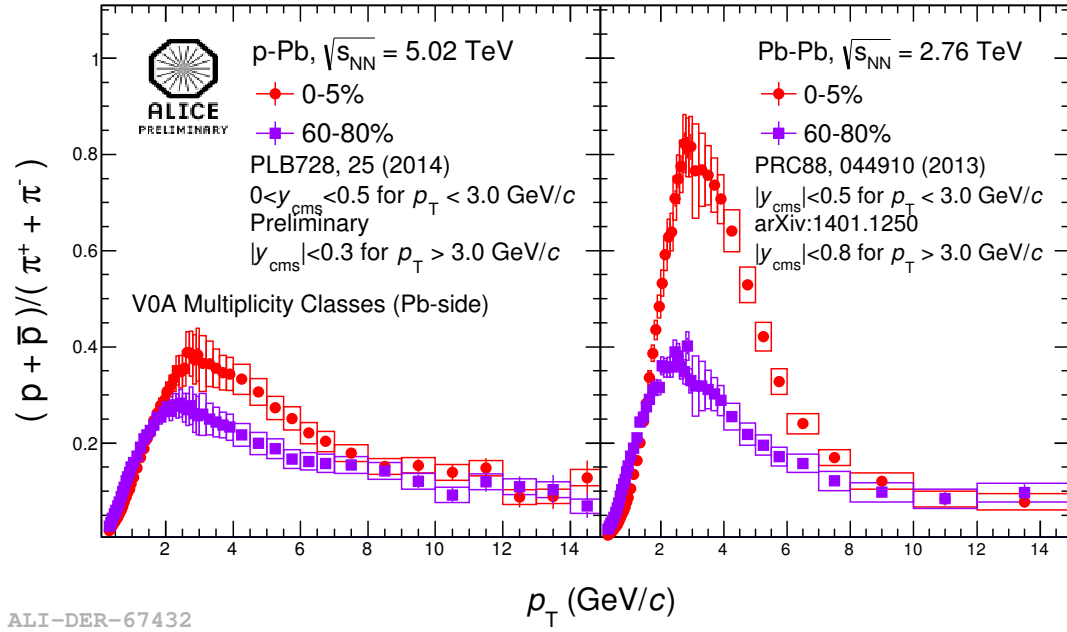


Figure 3. Proton-to-pion ratio as a function of p_T measured in p-Pb (left) and Pb-Pb (right) collisions at $\sqrt{s_{NN}} = 5.02$ and 2.76 TeV, respectively. The systematic and statistical uncertainties are plotted as boxes and error bars, respectively.

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